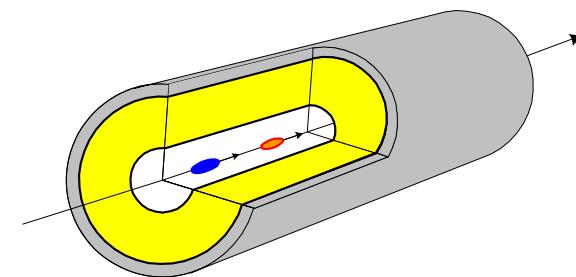
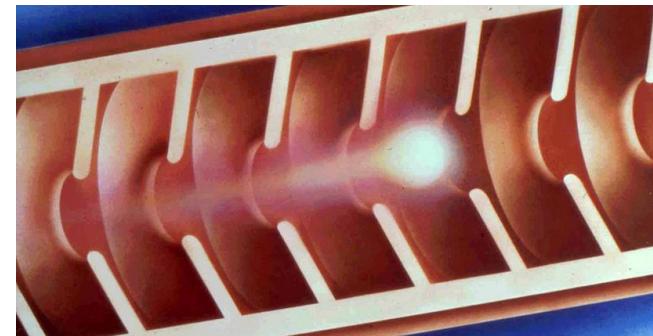


AE52: Beam Manipulation by Self-Wakefield at the ATF

Sergey Antipov

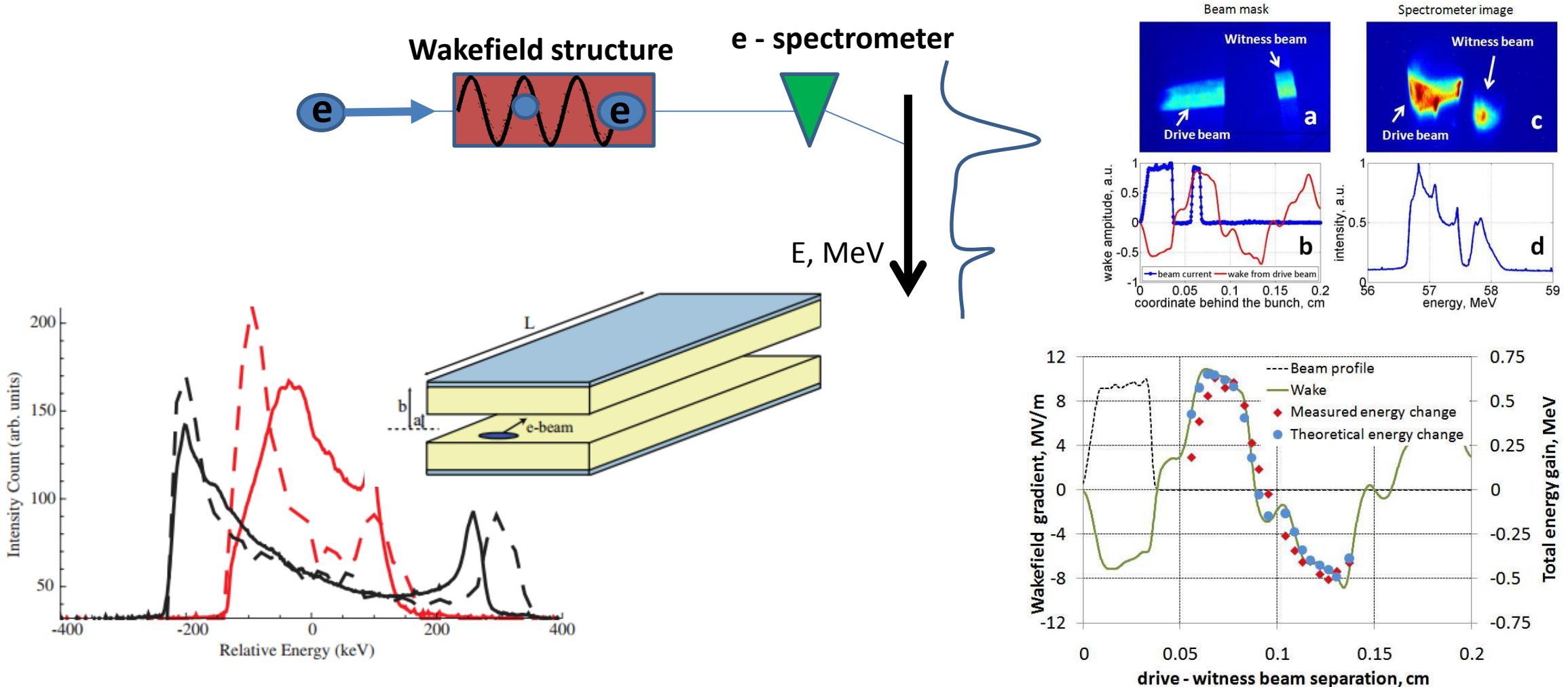
Euclid Techlabs LLC

- AE52 - Beam manipulation by self-wakefield
- Various structures
 - dielectric loaded, corrugated, single mode, multimode
- Study of wakefield (/THz)
- Study of self-wakefield
 - Dechirper, energy modulation, transformer ratio



$$W_z(z) \approx \frac{Q}{a^2} \exp\left[-2\left(\frac{\pi \sigma_z}{\lambda_n}\right)^2\right] \cos(kz)$$

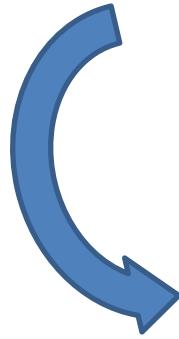
Collinear wakefield acceleration



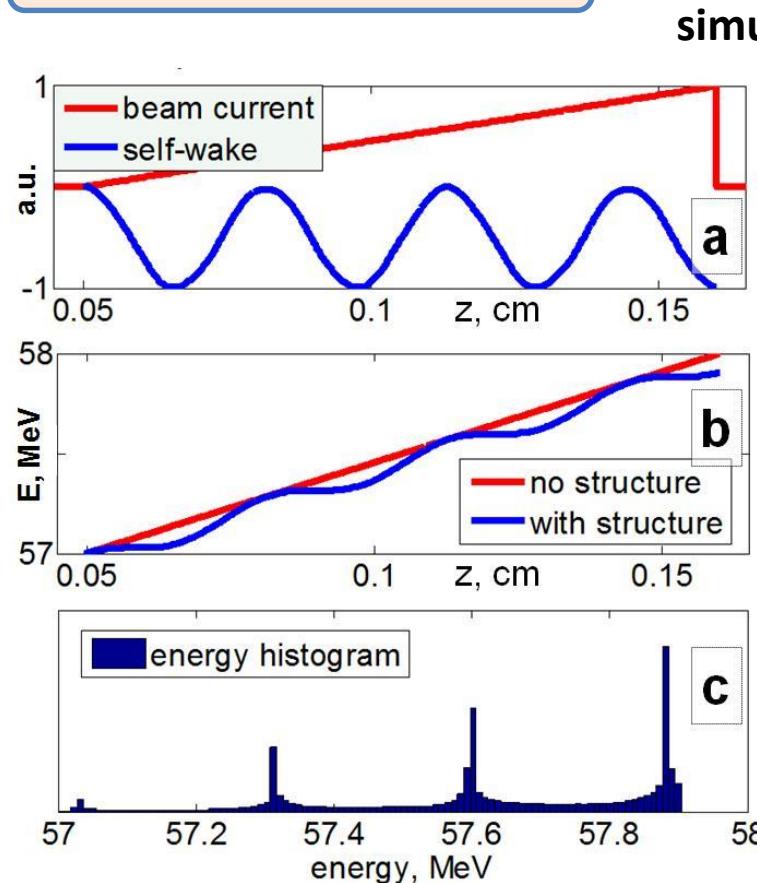
G. Andonian et.al PRL 108, 244801 (2012)

S. Antipov, et.al, Appl. Phys. Lett. 100, 132910 (2012)

Observation of energy modulation at ATF



Periodic self-deceleration!



Original chirped beam



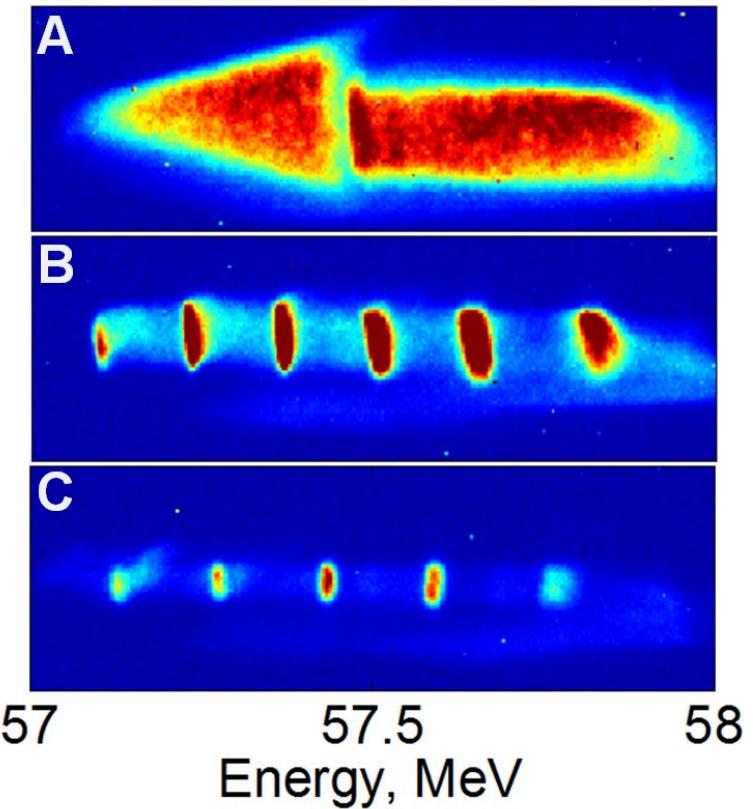
0.95 THz structure



0.76 THz structure



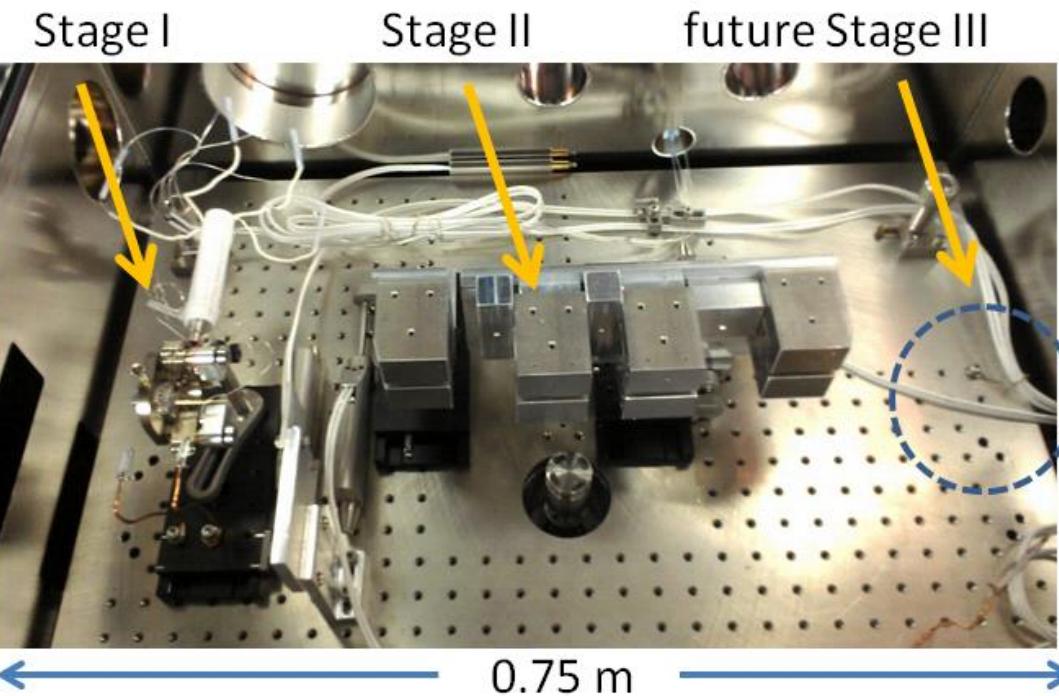
Measurement: spectrometer



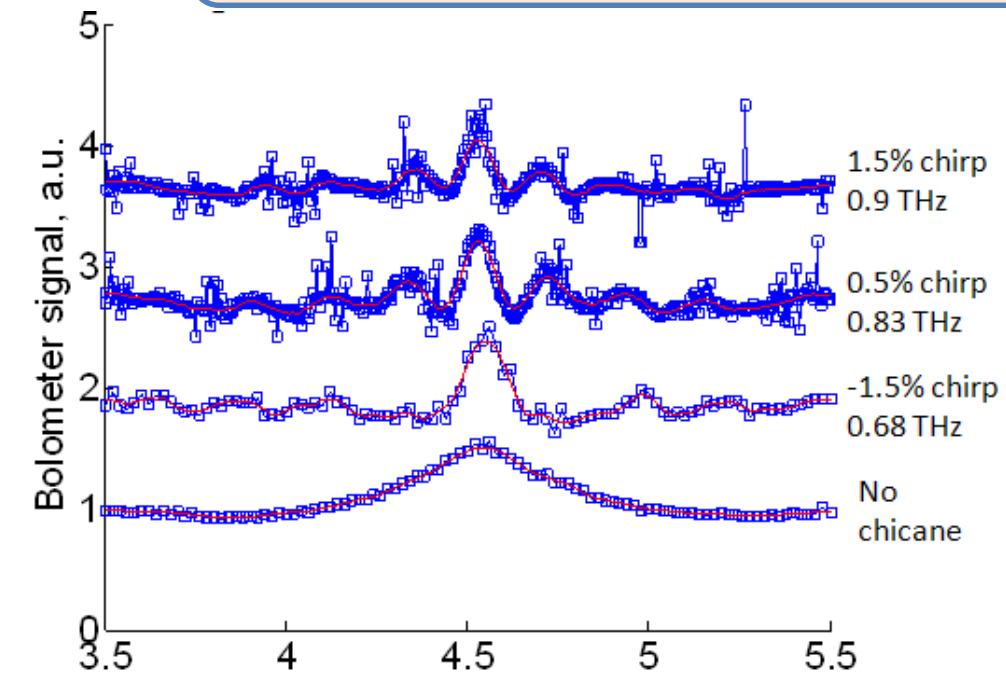
S. Antipov, et.al., Phys. Rev. Lett. 108, 144801 (2012)

Sub-picosecond bunch train production at ATF

PM chicane is used to convert energy modulation into density modulation



CTR interferometry shows that THz periodicity can be tuned by energy chirp



S. Antipov, et. al., Phys. Rev. Lett. 111, 134802 (2013)

We proposed a high power terahertz radiation source based on this scheme (electron beam wakefields). A third stage, yet another dielectric tube will be installed after chicane to coherently extract THz power from the bunch train

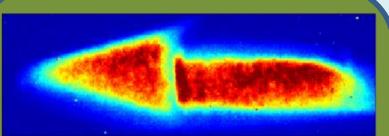
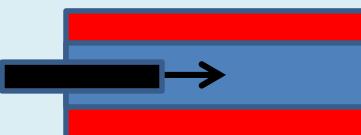
High power beam-based THz source

ATF (100A, 2.4mm) 6 MW peak, 0.7THz, 160ps pulse, 1%BW, 1.4mJ pulse

Stage I

S. Antipov, C. Jing et. al. Phys. Rev. Lett. 108, 144801 (2012)

Energy modulation via self-wakefield



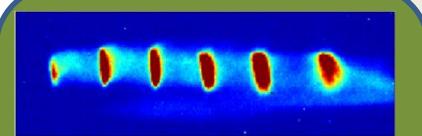
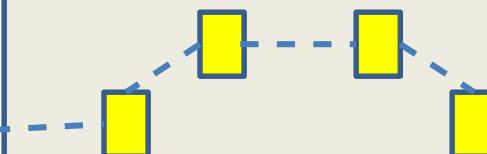
Measured beam spectrum
Energy chirped rectangular beam



Stage II

D. Xiang et. al PRL. 108, 024802 (2012)
S. Antipov, et. al., PRL. 111, 134802 (2013)

Chicane energy modulation conversion to bunch train



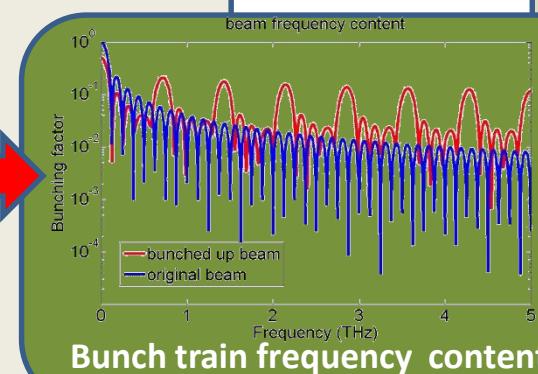
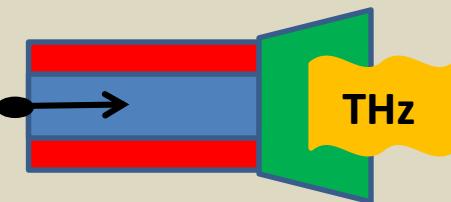
Measured beam spectrum
Energy modulated rectangular beam



Stage III

G. Andonian et. al. Appl. Phys. Lett. 98, 202901 (2011)
S. Antipov, et. Al. AAC 2014

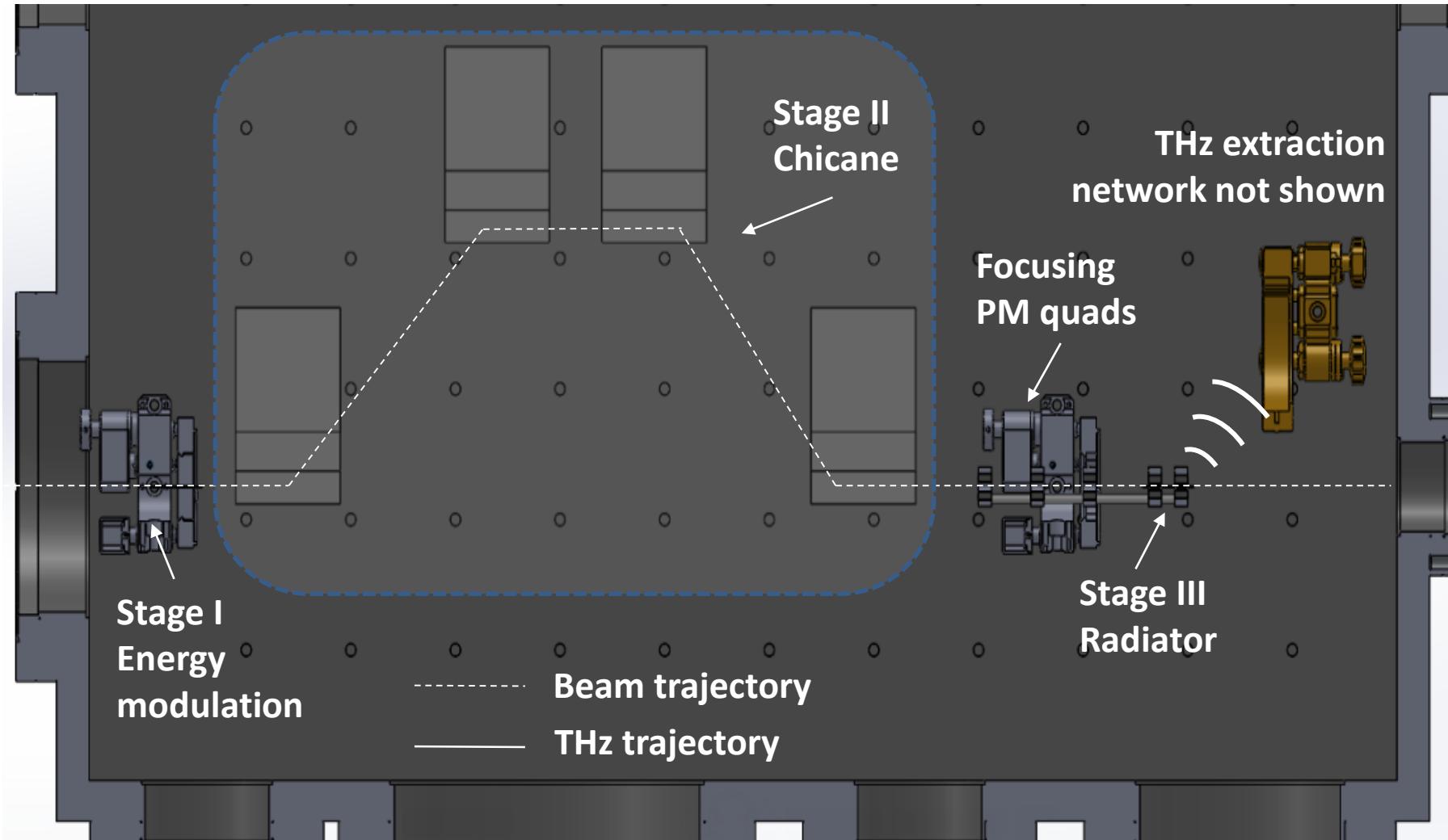
THz radiation wakefield structure



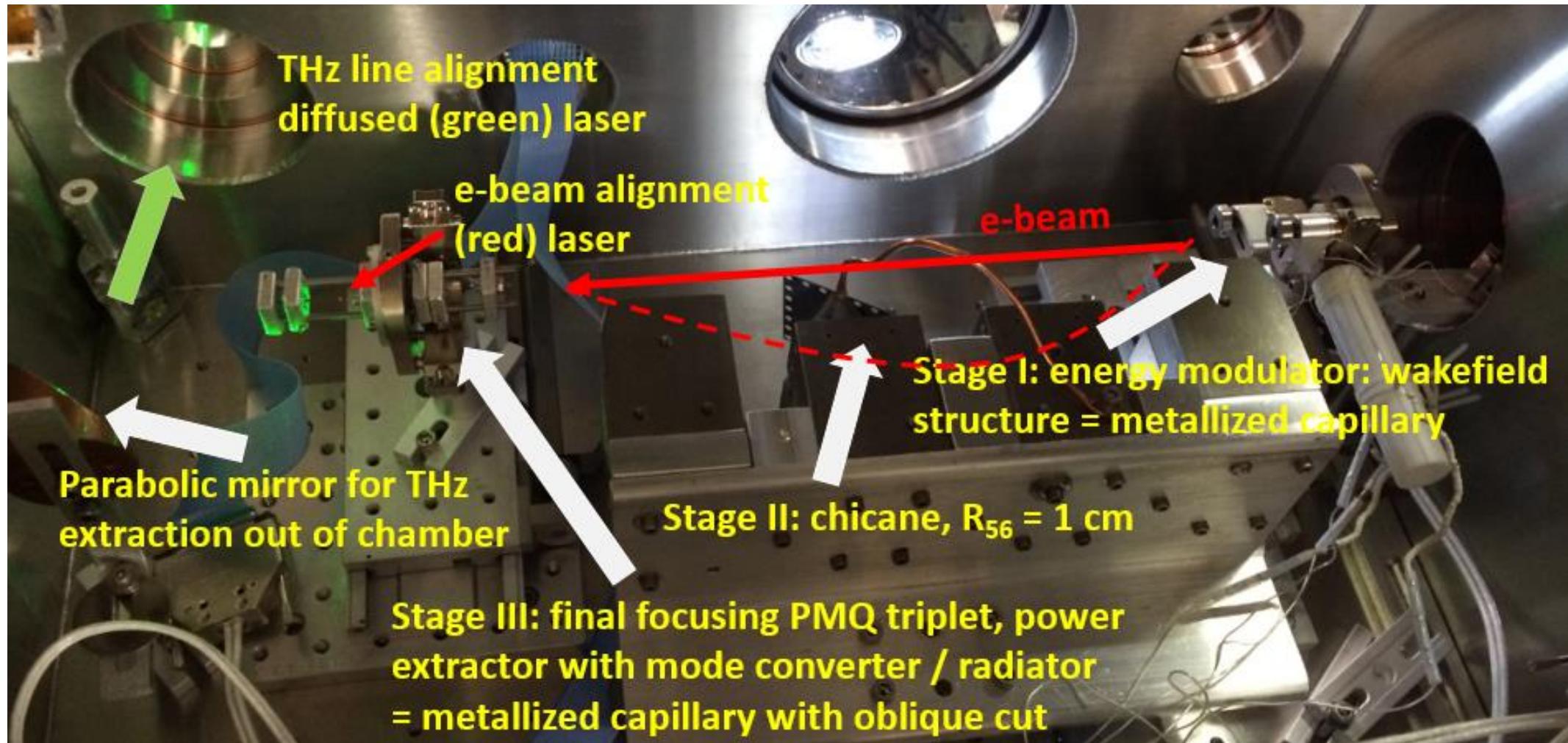
Tunable 100% source:
Range: 0.3-1.5 THz
Pulse bandwidth: 1%
Energy in pulse: ~ mJ

S. Antipov et. al., Rev. Sci. Instrum. 84, 022706 (2013)

Full – featured experiment layout

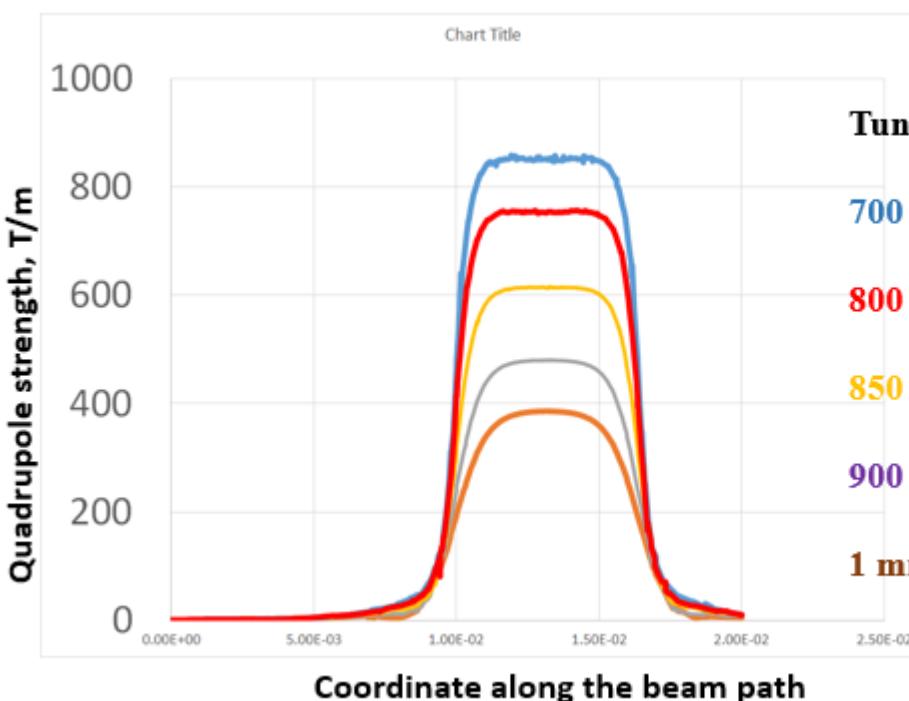


Full – featured experiment - 2016

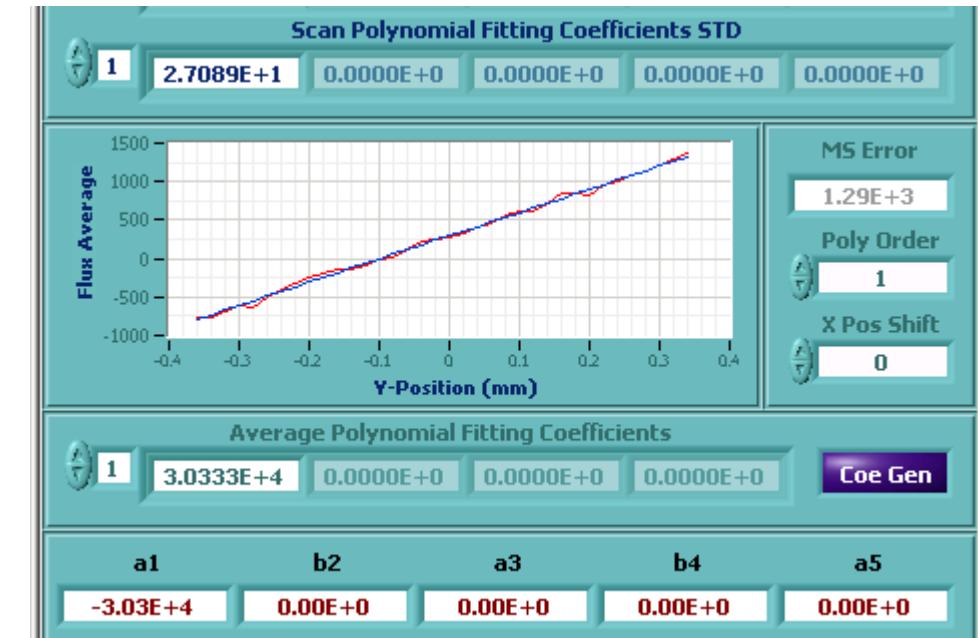


Poor beam transmission through the third stage due to beam-structure-quadrupole channel alignment

Quadrupole magnetic center misalignment



Stretched wire measurement



I. Vasserman, J. Xu, APS MD-TN-2016-003

Pulsed stretched wire measurement is required for quadrupole assemblies

Beam Break Up

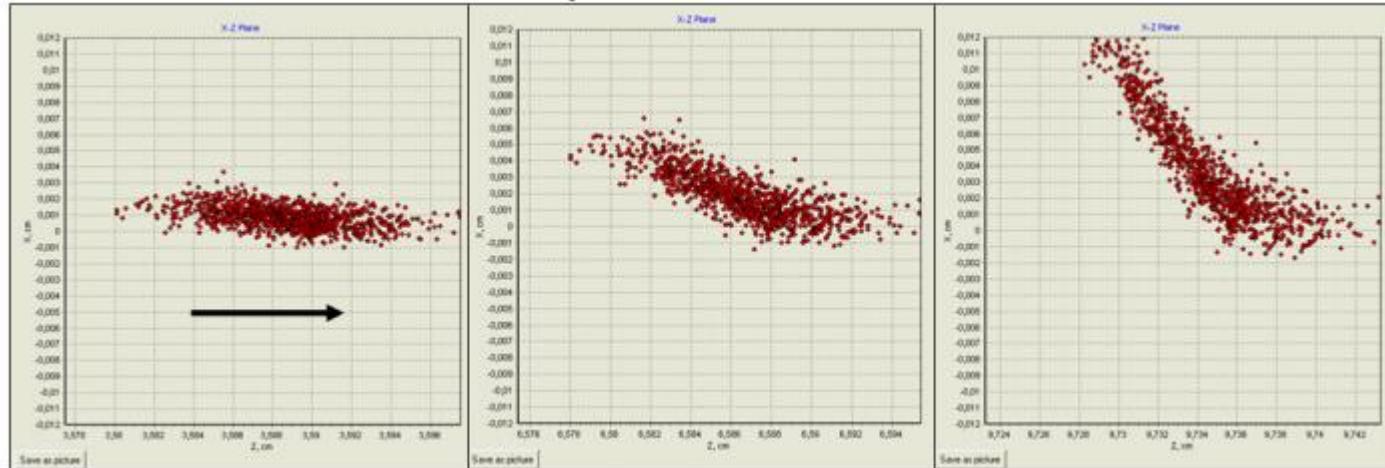
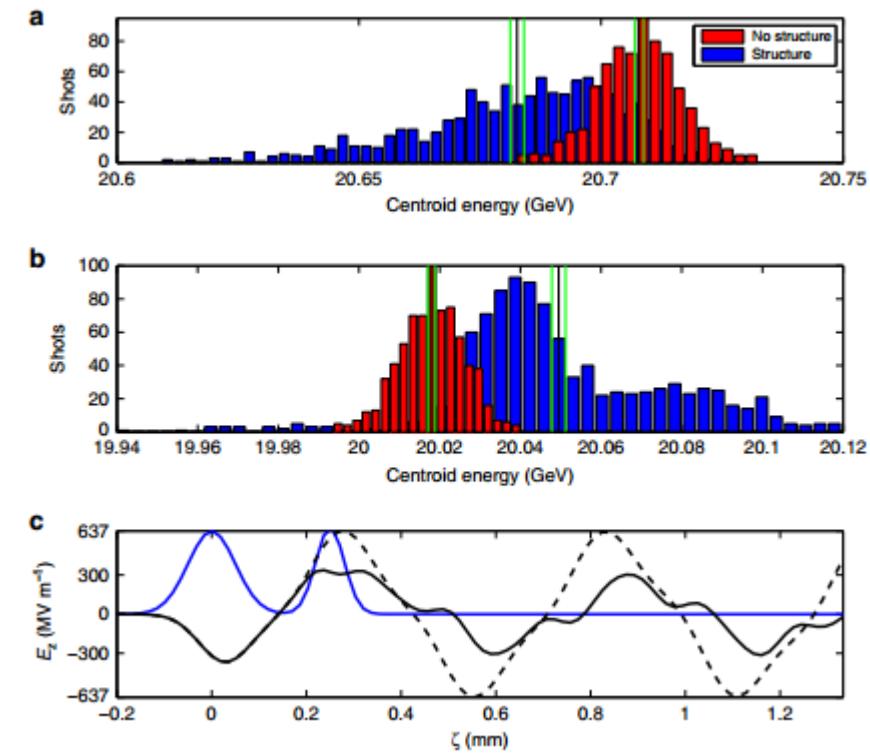


TABLE 1. Comparison of THz diamond DLAs for FACET beam.

	“small” tube	“medium” tube	“large” tube
Inner radius, μm	30	62.5	120
Outer radius, μm	65.3	92.5	144
Main mode in spectrum, THz	1	1	1
Gradient per 3 nC, GV/m	14	7	3.25
Initial transverse force, MV/m	2000	400	65
10% particle loss travel distance, cm	1.5	3.6	10.7

S. Antipov et.al., AAC 2010, AIP Conf. Proc. 1299, 359 (2010)



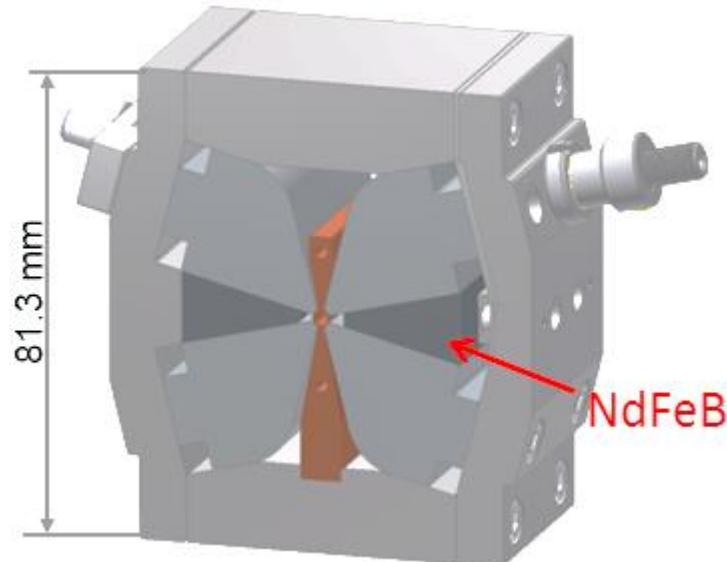
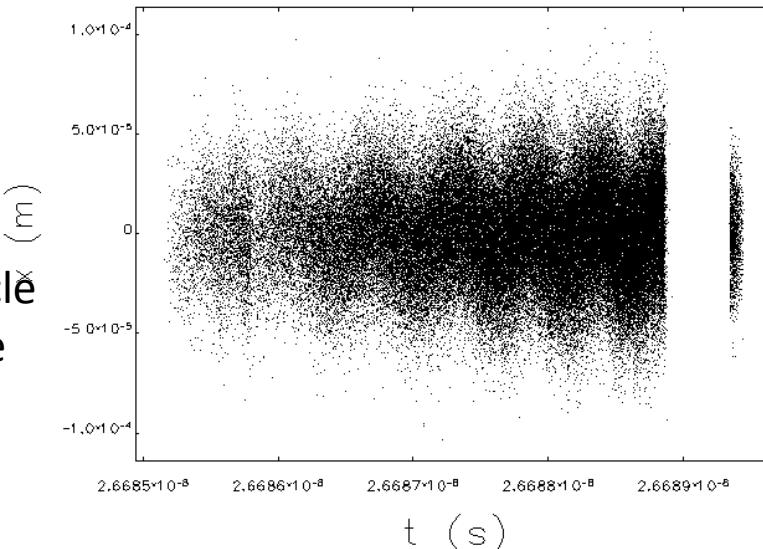
ID=400um, 15 cm long
quartz-Cu structure
320 MV/m gradient

B. O’Shea et.al., Nat.Comm. 7, 12763 (2016)

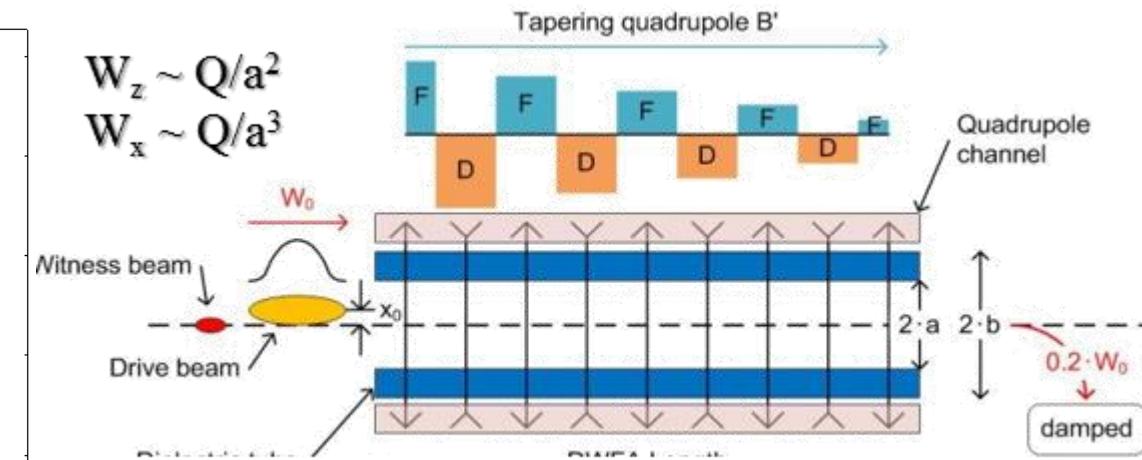
Multi-meter collinear wakefield acceleration

Use of **FODO lattice** for beam confinement

BNS damping, i.e., use of drive beam energy chirp to desynchronize transverse particle oscillations and thus reduce the resultant transverse electric wakefield

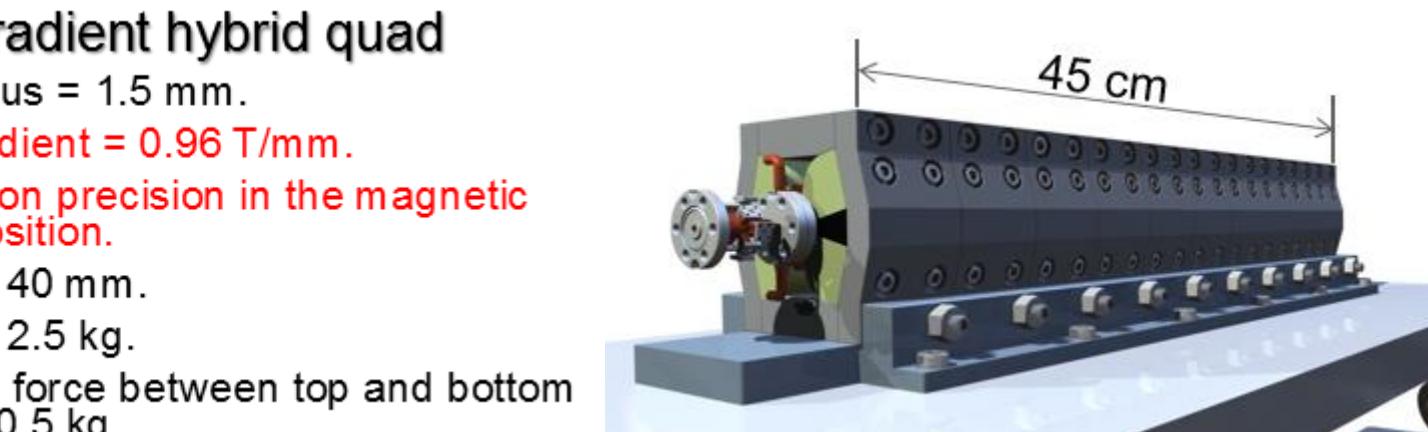


N. Strelnikov, A. Zholents



Dielectric channel imbedded into quadrupole wiggler

D. Shegolkov, E. Simakov (AAC 2014)

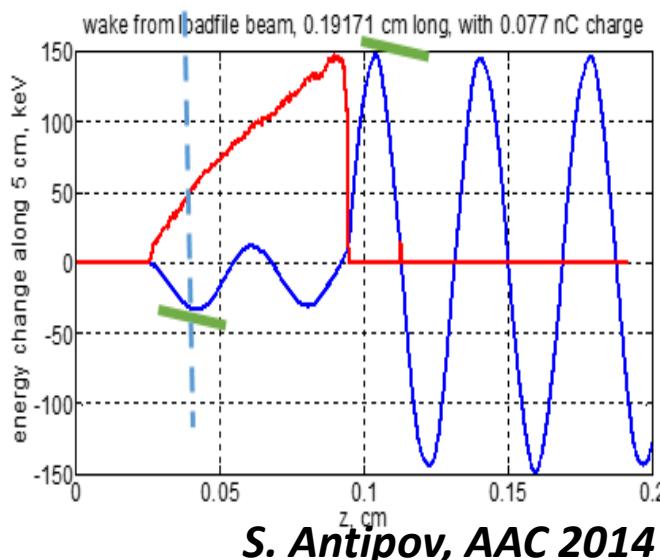


Collaboration: APS-AWA-Euclid-LANL

Transformer ratio measurement at ATF

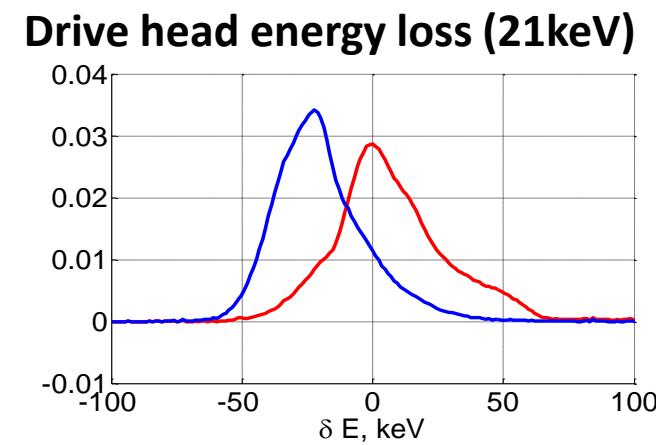
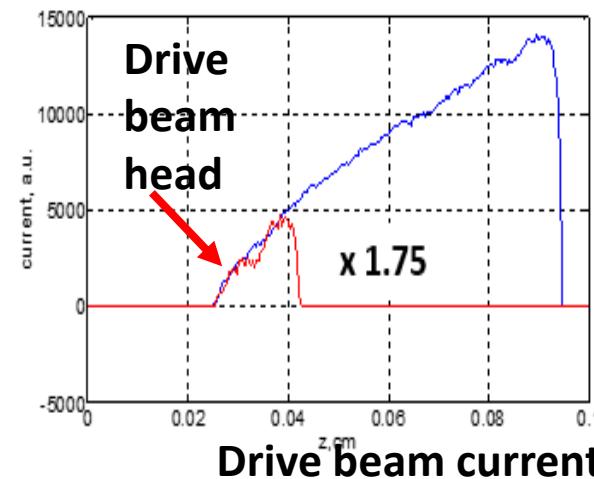
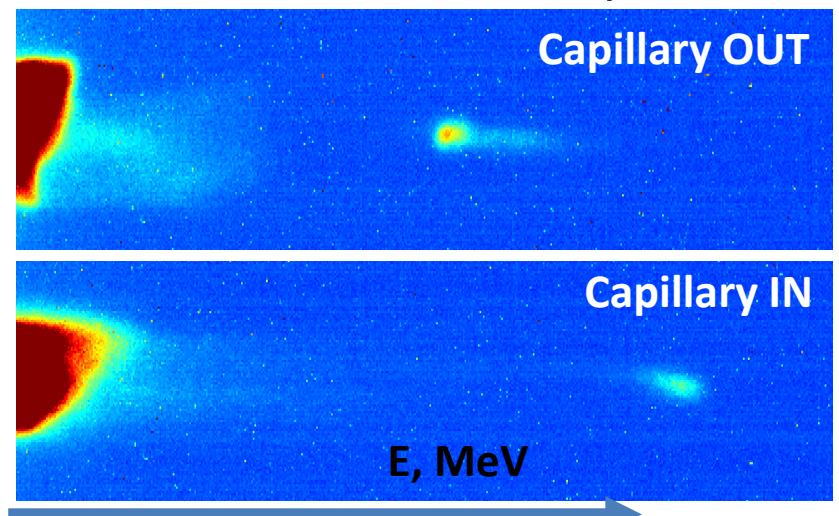
Beam profile after the mask in a dogleg

Drive (77 pC) and witness (3.5 pC)



Theoretical: 4.5
Measured: 3.5

- Small witness beam: spectrometer



Summary

POP experiments over the years:

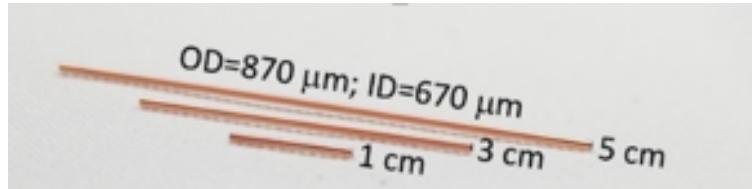
- Wakefield mapping
- Beam energy modulation
- Microbunching
- Tunable dechirping
- Enhanced transformer ratio measurement
- Numerous THz measurements:
 - DLA – cylindrical, planar
 - Corrugated structure (with K.Bane (SLAC))
 - Selective mode excitation in a multimode structure
 - Efficient power extraction
- Multistage THz generation experiment – limited by electron-optics and complex alignment

Future plans:

Long structures with embedded electron optics for beam confinement and BBU control

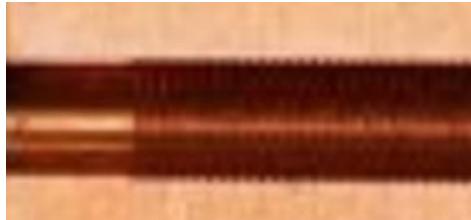
THz generation at ATF

Dielectric loaded waveguide



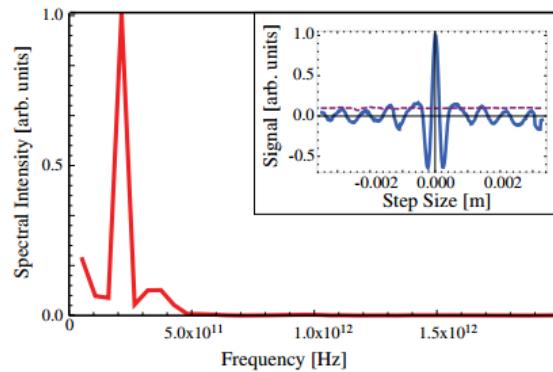
Numerous measurements by UCLA and Euclid

Corrugated waveguide

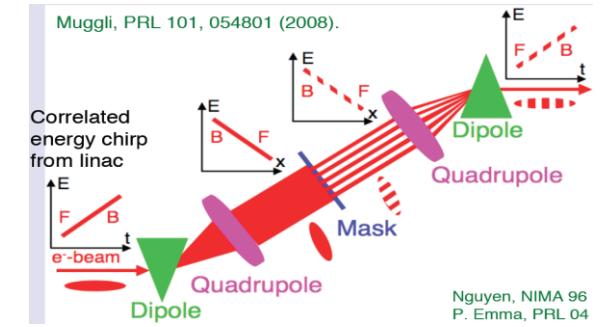


K. Bane (SLAC), S. Antipov
Accepted to NIM

Bragg structure

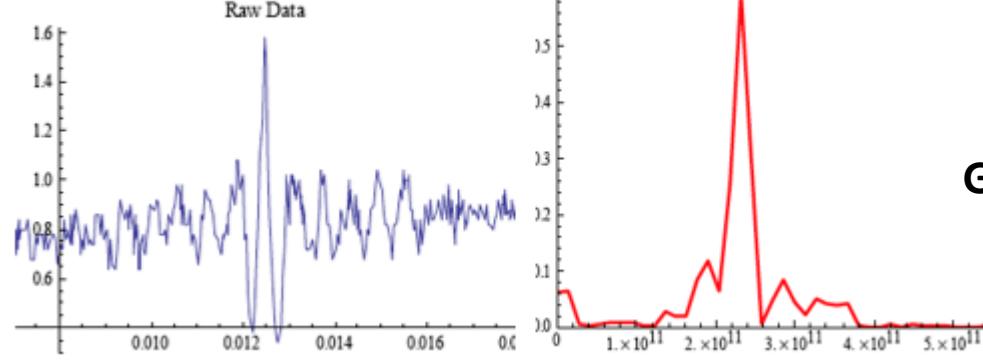


G. Andonian, PRL 113, 264801 (2014)

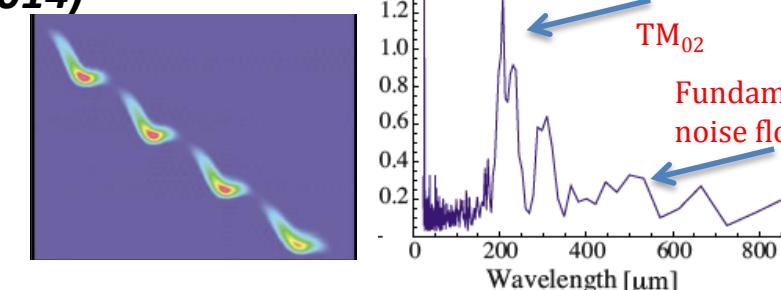


Woodpile structure

Interferogram

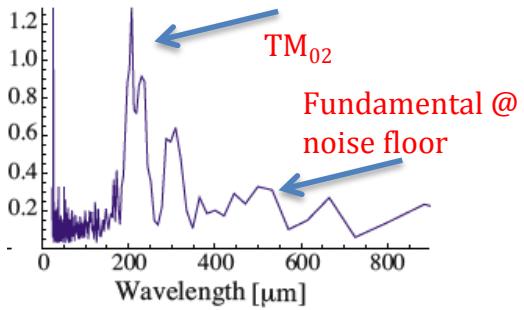
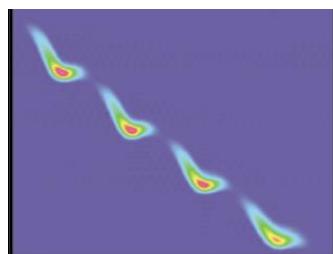
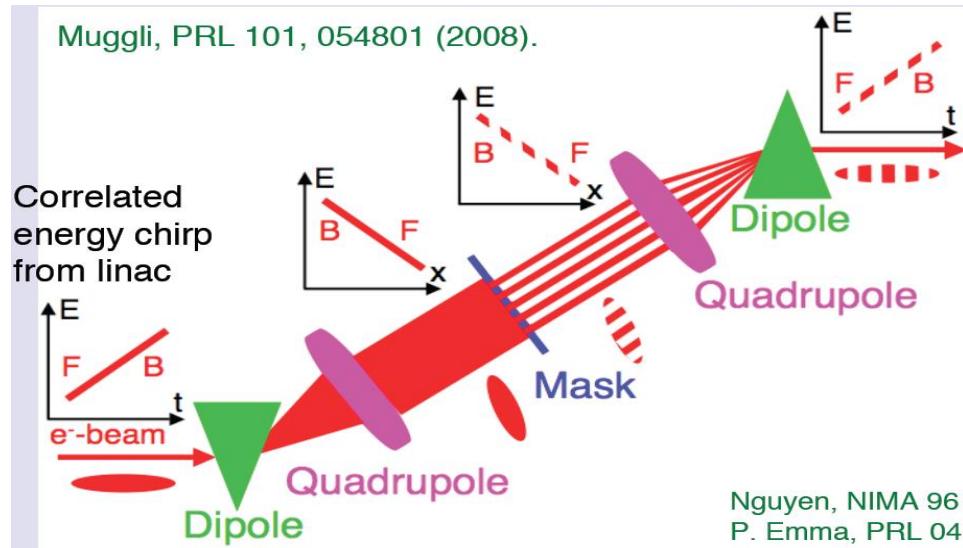


G. Andonian, P. Hoang, UCLA

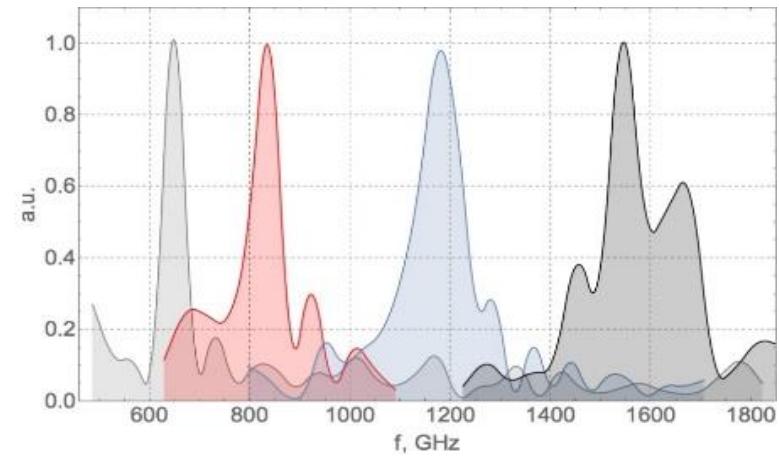
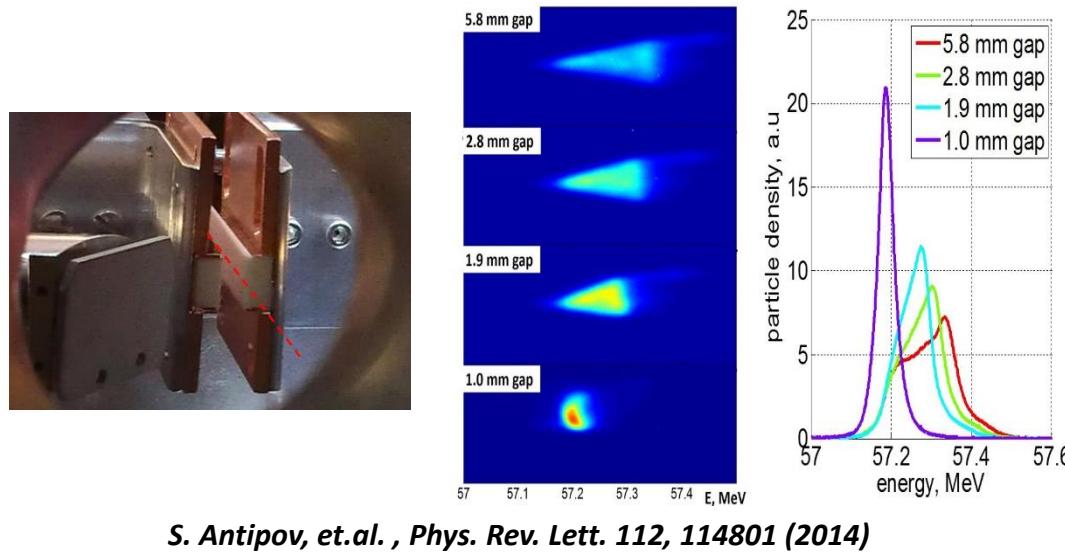


G. Andonian et al., APL 98, 202901 (2011)

Tunable: $f = 0.1 - 2$ THz, BW = 1-100%

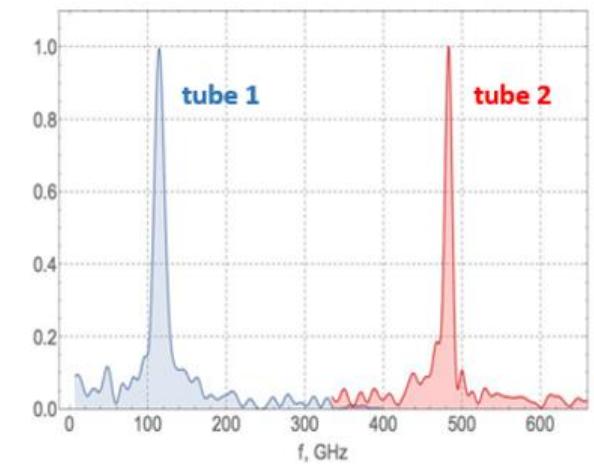
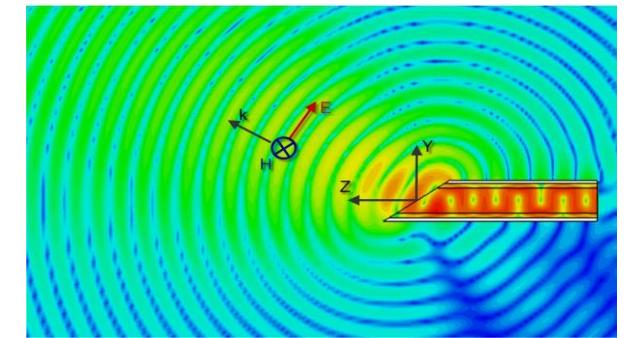
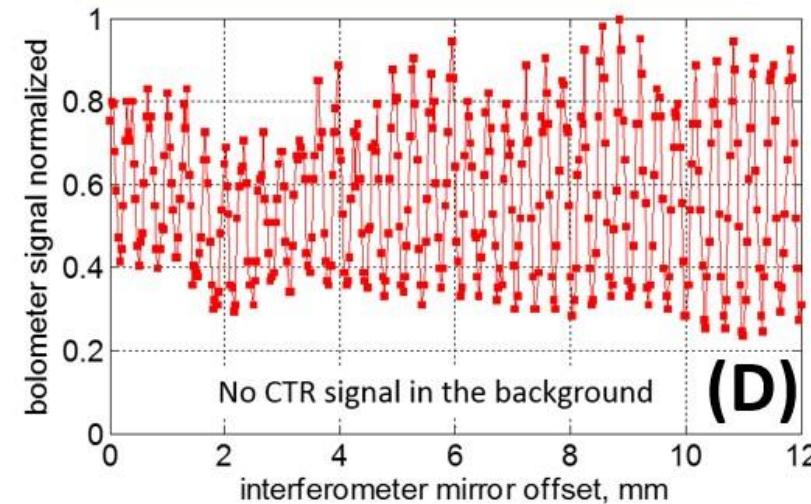
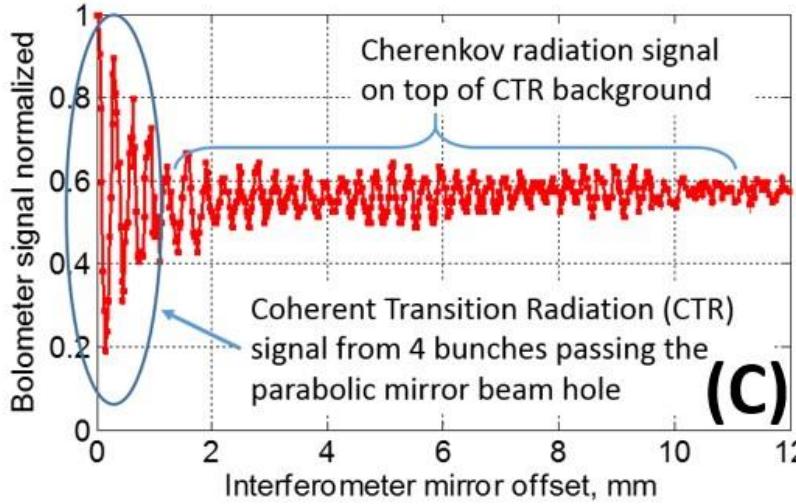
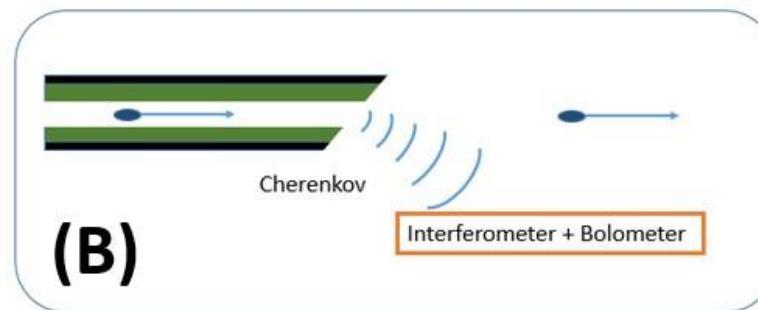
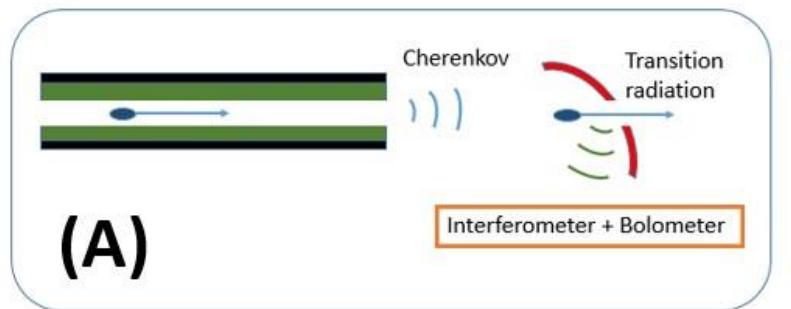


G. Andonian et al., APL 98, 202901 (2011)



S. Antipov et al., IPAC 2015

Efficient power extraction



S. Antipov, et.al. Appl. Phys. Lett. 109, 142901 (2016)

0.5 THz, 10uJ – outside the beamline available for experiments

Future plans

- Long DWFA with integrated FODO lattice
- THz “user” experiment (possible complementarity to UED program?)

Acknowledgements

- **Accelerator User Facility Team (ATF-BNL)**
- Dan Wang, Wei Gai, Sasha Zholents (ANL)
- R. Kostin, S. Baryshev, J. Qiu, N. Strelnikov, C. Jing (Euclid)
- Dmitry Schegolkov, Evgenya Simakov (LANL)